ATTACHMENT 1

ASSESSMENT OF THE NRC'S "POLICY ON FACTORS CAUSING FATIGUE OF OPERATING PERSONNEL AT NUCLEAR REACTORS"

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Executive Summary

On June 15, 1982, the U.S. Nuclear Regulatory Commission (NRC) published Generic Letter 82-12, which included the NRC's "Policy on Factors Causing Fatigue of Operating Personnel at Nuclear Reactors." The objective of this policy statement is to ensure, to the extent practicable, that personnel are not assigned to shift duties while in a fatigued condition. The generic letter requested that licensees revise their technical specifications (TS) to ensure that plant-specific administrative procedures are consistent with the guidelines presented in the NRC's policy statement. In 1999, the NRC responded to concerns regarding the implementation of the policy by conducting a preliminary review of the policy's implementation. The result of this review caused the staff to commit to assess the need to revise the policy. This report provides the findings from this assessment.

In March 2000, an NRC working group was formed to assess the policy. This group (1) reviewed the technical and research literature on the issues of fatigue and working hours; (2) collected information on working hour limits imposed in other industries to protect public safety and in the nuclear power industry in other countries; (3) analyzed survey data collected by the Nuclear Energy Institute (NEI) regarding the scope, authorization of deviations from the policy guidelines, and use of overtime; and (4) conducted preliminary evaluations of TSs, enforceability, and risk. The working group also contacted other Federal agencies to determine the status of their fatigue-related programs.

Studies of work scheduling, fatigue, and human performance indicate that the policy allows more hours of work and less rest than the amounts these studies would suggest for ensuring that personnel are not impaired by work-related fatigue. Consistent with this finding, a comparison of the policy guidelines with regulatory limits in other industries where work hours are controlled to protect public safety, and with the work hour limits for personnel at nuclear power plants in other countries, shows that the NRC's policy statement is the least restrictive. Further, the staff's review of plant-specific TSs and data collected by NEI reveals inconsistent implementation of the policy statement with a substantial minority of plants authorizing more guideline deviations than suggested by policy guidance to limit deviations to "very unusual circumstances." The staff also finds that the general and nonmandatory wording of the TSs and related requirements of the *Code of Federal Regulations*, Title 10, Part 26, "Fitness for Duty Programs" (10 CFR Part 26) makes the current regulatory framework difficult to achieve effective and efficient enforcement concerning working hours and fatigue. Despite these findings, few events have been attributed to fatigue at U.S. nuclear power plants. This may be in part the result of the levels of defense-in-depth at nuclear power plants which are designed to reduce the potential for personnel errors to have consequential effects on plant safety. However, the staff notes that difficulties in substantiating fatigue as a cause of an event suggest that the number of events attributed to fatigue should be interpreted with caution and cannot be reported with certainty. In addition, a preliminary study to test the sensitivity of plant core damage frequencies (CDF) to potential changes in human error probabilities caused by fatigue indicates that the effects of personnel fatigue may be risk significant, with increases in CDF on the order of 1E-5/yr.

Having considered these collective findings, the staff believes that the NRC's policy statement has weaknesses that have diminished its effectiveness. However, the staff also believes that there is an adequate technical basis and relevant experience to develop new requirements that

are technically sound and practical in a nuclear plant operational setting. A potential model for such an initiative is the “Fatigue Management” approach that is being pursued by some industries in the United States and abroad. Fatigue management addresses the multiple causes of fatigue through measures that include prevention (e.g., work hour limits, rest requirements, training, and health screening), detection and monitoring, mitigation, and evaluation.

Assessment of the NRC's Policy on Factors Causing Fatigue of Operating Personnel at Nuclear Reactors"

By letter dated February 25, 1999, Congressmen Dingell, Klink, and Markey expressed concerns to former NRC Chairman Shirley Ann Jackson that low staffing levels and excessive overtime may present a serious safety hazard at some commercial nuclear power plants. Similar concerns were expressed in a letter dated March 18, 1999, from David Lochbaum of the Union of Concerned Scientists (UCS) to Chairman Jackson, and in the UCS report, "Overtime and Staffing Problems in the Commercial Nuclear Power Industry." In response to these concerns, the staff conducted a preliminary review and found that few events at nuclear power plants had been attributed to fatigue. However, the staff acknowledged that the number of events attributable to fatigue could not be reported with certainty. Further, NRC inspectors had identified several instances each year in which licensees' use of overtime appeared to be inconsistent with the NRC's "Policy on Factors Causing Fatigue of Operating Personnel at Nuclear Reactors" (policy). By letter dated May 18, 1999, the Chairman informed the Congressmen of the staff's findings and stated that the staff would assess the need to revise the policy statement. During the development of an action plan to assess the policy, the NRC received a petition for rulemaking (PRM-26-2), dated September 28, 1999, from Barry Quigley. The petition requests that the NRC amend 10 CFR Parts 26 and 55 to establish clear and enforceable working hour limits to mitigate the effects of fatigue for nuclear power plant personnel performing safety-related work. The staff subsequently established a working group to concurrently process PRM-26-2 and assess the policy.

1.0 History of Policy Development

Following the accident at Three Mile Island, inspection activities conducted by the U.S. Nuclear Regulatory Commission (NRC), together with concerns expressed by some licensed operators, indicated that in certain situations, facility personnel were either required or allowed to remain on duty for extended periods of time. On February 1, 1980, the NRC issued Inspection and Enforcement (IE) Circular No. 80-02, "Nuclear Power Plant Staff Work Hours," which described concerns regarding the effects of fatigue on human performance. In conclusion, the circular stated that licensees should review their administrative procedures to ensure that they establish a sound policy regarding working hours for plant staff who perform safety-related functions. The NRC provided the following interim guidelines: (1) individuals should work no more than 12 hours straight, and no more than 72 hours in a 7-day period; (2) there should be a break of at least 12 hours between work periods; (3) individuals should not work more than 14 consecutive days without having 2 consecutive days off; (4) if an operator is required to work more than 12 hours, the individual's duties should be carefully selected; and (5) special circumstances requiring deviations from these guidelines should be authorized by the station manager.

The guidance provided in IE Circular No. 80-02 was later superseded by a letter dated July 31, 1980, from the Director of the Division of Licensing, Office of Nuclear Reactor Regulation, to all licensees of operating plants and applicants for operating licenses. The letter stated that licensees' administrative procedures shall include a policy concerning overtime work for senior reactor operators (SROs), reactor operators (ROs), and shift technical advisors (STAs). The procedures are to stipulate that overtime shall not be routinely scheduled to compensate for an

inadequate number of personnel. In addition, the letter established specific overtime restrictions, which were generally consistent with those in IE Circular No. 80-02. However, the limitation regarding working no more than 12 hours was qualified to exclude turnover time, and the guidance was clarified to indicate that the use of overtime should be limited to unavoidable or unanticipated circumstances.

On October 30, 1980, the NRC issued NUREG-0737, "Clarification of TMI Action Plan Requirements." Item I.A.1.3.1, "Limit Overtime," of NUREG-0737 required licensees to establish administrative procedures that set forth a policy for controlling overtime. NUREG-0737 also recommended overtime restrictions that were generally consistent with those contained in IE Circular No. 80-02. As in the letter of July 31, 1980, NUREG-0737 stipulated that the overtime restrictions apply in the event that overtime must be used. However, the guidance was not applicable during extended periods of shutdown, and contrary to the letter dated July 31, 1980, was not applicable to STAs.

On February 18, 1982, the NRC published its “Policy on Factors Causing Fatigue of Operating Personnel at Nuclear Reactors” (policy) (47 FR 7352). The objective of the policy statement was to ensure, to the extent practicable, that personnel are not assigned to shift duties while in a fatigued condition that could significantly reduce their mental alertness or decisionmaking ability. Generic Letter (GL) 82-02, "Nuclear Power Plant Staff Working Hours," dated February 8, 1982, disseminated the policy statement as information, and stated that the NRC would request that all licensees revise the administrative section of their technical specifications (TSs) to require procedures that follow the guidelines presented in the policy statement. Following issuance of the policy statement, industry feedback caused the staff to issue a revised policy statement (Table 1).

The revised policy statement was published in the *Federal Register* (47 FR 23836, June 1,1982) and disseminated by GL 82-12, "Nuclear Power Plant Staff Working Hours," dated June 15, 1982. The revised policy statement clarified that (1) the objective is to have operating personnel work an 8-hour day and a 40-hour week, (2) the limits in the policy statement apply during extended periods of shutdown, and (3) the requirement to consider use of overtime on an individual basis does not apply during periods when the plant is shutdown.

The NRC subsequently developed model TSs, which were provided for reference by GLs 82-16 (September 20, 1982) and 83-02 (January 10,1983), both of which were entitled "NUREG-0737 Technical Specifications." The NRC chose not to impose the TSs by order, and portions of the policy statement were incorporated (directly or by reference) into the TSs of all but three U.S. commercial nuclear power units. On March 7, 1983, the NRC issued GL 83-14, "Definition of ‘Key Maintenance Personnel’ (Clarification of Generic Letter 82-12)," to clarify the applicability of the policy statement to maintenance personnel.

The staff previously considered incorporating guidance on working hour limitations into Regulatory Guide (RG) 1.33, "Quality Assurance Program Requirements," which would have endorsed American National Standards Institute/American Nuclear Society (ANSI/ANS) 3.2, "Administrative Controls and Quality Assurance for the Operating Phase of Nuclear Power Plants." Both ANSI/ANS 3.2, 1982 and 1988, include guidelines on working hours that are similar to the policy statement. However, the standard did not include all facets of the policy and the staff has not issued a revision to RG 1.33.

Table 1. Policy on Factors Causing Fatigue of Operating Personnel at Nuclear Reactors

Licensees of operating plants and applicants for operating licenses shall establish controls to prevent situations where fatigue could reduce the ability of operating personnel to keep the reactor in a safe condition. The controls should focus on shift staffing and the use of overtime--key job-related factors that influence fatigue.

The objective of the controls would be to assure that, to the extent practicable, personnel are not assigned to shift duties while in a fatigued condition that could significantly reduce their mental alertness or their decision making capability. The controls shall apply to the plant staff who perform safety-related functions (e.g., senior reactor operators, reactor operators, health physicists, auxiliary operators, and key maintenance personnel).

Enough plant operating personnel should be employed to maintain adequate shift coverage without routine heavy use of overtime. The objective is to have operating personnel work a normal 8-hour day, 40-hour week while the plant is operating. However, in the event that unforeseen problems require substantial amounts of overtime to be used, or during extended periods of shutdown for refueling, major maintenance or major plant modifications, on a temporary basis, the following guidelines shall be followed:

a. An individual should not be permitted to work more than 16 hours straight (excluding shift turnover time).

b. An individual should not be permitted to work more than 16 hours in any 24-hour period, nor more than 24 hours in any 48-hour period, nor more than 72 hours in any seven day period (all excluding shift turnover time).

c. A break of at least eight hours should be allowed between work periods (including shift turnover time).

d. Except during extended shutdown periods, the use of overtime should be considered on an individual basis and not for the entire staff on a shift.

Recognizing that very unusual circumstances may arise requiring deviation from the above guidelines, such deviation shall be authorized by the plant manager or his deputy, or higher levels of management. The paramount consideration in such authorization shall be that significant reductions in the effectiveness of operating personnel would be highly unlikely. In addition, procedures are encouraged that would allow licensed operators controls to be periodically relieved and assigned to other duties away from the control board during their tour of duty.

2.0 Assessment Approach

The policy assessment was composed of several activities to provide a comprehensive assessment of the policy and facilitate identifying options for resolving potential deficiencies. The activities included (1) an assessment of the technical adequacy of the guidelines for ensuring that personnel are not impaired, (2) a review of the implementation of the policy through technical specifications, (3) an assessment of the adequacy of plant technical specifications and Part 26 fitness for duty requirements for enforcement actions related to plant personnel working hours and fatigue, (4) a comparison of work scheduling practices at nuclear power plants relative to the policy guidelines, (5) an assessment of the incidence of events attributed to fatigue at nuclear power plants, (6) a preliminary assessment of the sensitivity of plant core damage frequencies to fatigue-induced impairment of plant personnel, (7) and a survey of limits and controls for addressing fatigue in other industries and for nuclear plant personnel in other countries.

To conduct the assessment, the staff (1) reviewed the technical and research literature on the issues of fatigue and working hours; (2) collected information on working hour limits imposed in other industries to protect public health and safety and in the nuclear power industry in other countries; (3) analyzed survey data collected by the Nuclear Energy Institute (NEI) regarding the scope, authorization of deviations, and use of overtime; and (4) conducted preliminary evaluations of TSs, enforceability, and risk. The working group also contacted other Federal agencies to determine the status of their fatigue-related programs, including fatigue management.

3.0 Technical Adequacy of the Policy Statement

This section presents a detailed assessment of each element of the policy statement. The individual elements of the policy statement are paraphrased in italics and grouped as: Policy Statement Objectives, Scope of Personnel Covered, Pre-Conditions for Authorizing Guideline Deviations, Work Limits and Rest Requirements, and Guideline Deviation Criteria. Relevant technical findings and bases follow the statement of each individual element to provide insights concerning the relationship between working hours, fatigue, and personnel impairment or performance. The staff notes that nuclear power plants are designed, and their operation controlled, in a manner to minimize the consequences of potential human errors on plant operational safety. As a consequence, there are measures and barriers, in addition to work hour controls, that can reduce the probability of fatigue-induced errors resulting in events leading to core damage or off-site release of radioactive materials. These measures and barriers include plant design characteristics (e.g., fail-safe components, redundant and independent emergency safeguards features) and programmatic controls (e.g., independent verification, post-maintenance testing, and surveillance tests).

Policy Statement Objectives – The general objectives of the policy are based on the premise that fatigue can lead to impaired performance. A large body of scientific literature demonstrates that long work hours cause fatigue and degraded human performance.

Establish controls to prevent situations where fatigue could reduce the ability of operating personnel to keep the reactor in a safe condition - the controls should focus on shift staffing and the use of overtime.

- Excessive working hours and shift work cause fatigue (Akerstedt, 1995; Rosa, 1995).
- Fatigue impairs human performance (Harrison and Horne, 2000; Williamson, 2000; Bobko et al., 1998; Dawson and Reid, 1997; Dinges, 1995; Dinges, 1992; Rosa, 1991).
- Human performance impacts on plant safety, as shown in studies on plant risk (U.S. Nuclear Regulatory Commission, 2000; NUREG-1560, 1997).
- Information Notice 91-36 cited several examples in which NRC inspection revealed that plant staff had worked excessive hours while performing safety-related functions.

Assure that, to the extent practicable, personnel are not assigned to shift duties while in a fatigued condition that could significantly reduce their mental alertness or their decisionmaking capability.

- The ability of people to perform and remain alert varies throughout the day and depends upon underlying physiological processes that operate on a circadian cycle. Human error can increase during circadian ebbs, which occur during certain times of the day and night. By its nature, shift work is an around-the-clock activity that requires personnel to work during periods that are contrary to their internal circadian clocks (Mitler and Miller, 1996; Kecklund et al., 1997; Mitler and Miller, 1997; Folkard, 1997; Bobko et al., 1998).
- Long working hours exacerbate the adverse effects of circadian cycles in alertness (Hanecke, 1998).
- In studies that compared fatigue to blood alcohol concentration (BAC), individuals who were awake for 17 to 19 hours had cognitive psychomotor performance comparable to individuals with a BAC of 0.05 percent (Williamson and Feyer, 2000; Dawson and Reid, 1997).
- Harrison and Horne (2000) reviewed the impact of sleep deprivation on decisionmaking and found that, contrary to popular belief, sleep deprivation impairs decisionmaking even if individuals try to compensate for lack of sleep when responding to heightened stimulation.
- The National Transportation Safety Board (NTSB) reviewed the performance of flight crews involved in major accidents and found that those crew members who had been awake longer than 12 hours before their accidents made more errors overall, and specifically more tactical decision errors, than did crew members who had been awake for less time (NTSB, 1994).
- Fatigue has generalized effects on human performance capabilities. Some of these effects include degraded short-term memory, impaired ability to recognize proper grammar, reduced aversion to risk, and degraded communication behaviors (Dinges, 1995).

Enough plant operating personnel should be employed to maintain adequate shift coverage without routine heavy use of overtime.

- The term “routine heavy use of overtime” is not defined, and no guidance is provided for the related limits.

- Data collected by the NEI (see Section 6) demonstrate that, at some sites, personnel who are covered by the policy statement are assigned considerable amounts of overtime.

The objective is to have operating personnel work a normal 8-hour day, 40-hour week while the plant is operating.

- Lack of adequate days off and extended workdays (overtime) can result in cumulative sleep debt and performance impairment (Williamson and Feyer, 2000; Tucker, 1999; Department of Transportation (DOT), 65 FR 25546; Colquhoun, 1996; Baker et al., 1994; Webb and Agnew, 1974).
- Guidelines issued by the Electric Power Research Institute (EPRI) with regard to preventing fatigue recommend that individuals work no more than four consecutive 12-hour shifts (Baker, 1990).
- When acute sleep loss is sustained (especially beyond 36 hours of sleep deprivation), everyone eventually suffers marked performance deficits (Dinges, 1995).

Scope of Personnel Covered - Industry data demonstrate that there is inconsistency among sites with regard to both the number and the type of personnel covered. This information indicates a need for clearer scope requirements.

The controls shall apply to the plant staff who perform safety-related functions (e.g., senior reactor operators, reactor operators, health physicists, auxiliary operators, and key maintenance personnel).

- GL 83-14 defined key maintenance personnel as those personnel who are responsible for the correct performance of maintenance, repair, modification, or calibration of safety-related structures, systems, or components.
- GL 83-14 included personnel performing or immediately supervising the performance of safety-related functions.
- Licensees, through administrative procedures, defined the scope of personnel at a site that were subject to administrative control of working hours.
- Data collected by the NEI (see Section 6) demonstrate that there is inconsistency among sites with regard to both the number and the type of personnel covered (e.g., a few sites do not cover any maintenance personnel).

Pre-conditions for Authorizing Guideline Deviations

In the event that unforeseen problems require substantial amounts of overtime to be used, or during extended periods of shutdown for refueling, major maintenance or major plant modifications, on a temporary basis, the following limits shall be followed:

- The terms “unforeseen problems” and “substantial amounts of overtime” are not defined, and no guidance is provided.
- The term “temporary basis” is not defined, and no guidance is provided. Also, the policy statement is not clear with regard to extended outages.

Work Hour Limits and Rest Requirements – The policy limits on work hours (16 hours in a 24 hour period, 72 hours in any 7-day period) and the requirement for a minimum 8-hour break

between work periods appear to allow more hours of work and less rest than current research indicates is appropriate for ensuring personnel are not impaired by work-related fatigue. Research concerning cumulative fatigue suggests that the NRC should consider requirements to address the prolonged use of extended work hours of duties for personnel working in excess of this limit. The relaxation that the policy statement allows for work scheduling during outages may no longer be consistent with the staff's understanding of plant risk during shutdown conditions.

An individual should not be permitted to work more than 16 hours straight (excluding shift turnover time) and an individual should not be permitted to work more than 16 hours in any 24-hour period.

- The original policy guidance was a maximum of 12 hours with careful selection.
- The Commission revised the limit from a recommended 12-hour maximum to 16 hours in response to practical concerns that the 12-hour limit required personnel working 8-hour shifts to split shifts when working overtime. This constraint was particularly problematic for using overtime to cover a night shift, as it would require a person to be called in the middle of the night. Therefore, keeping someone over for a full 8 hours is more practical.
- This limit is intended to prevent acute fatigue, but the limit of 16 hours is inconsistent with research findings and the practice in other industries and in the nuclear industry in other countries.
- Human reliability analysis experts have recommended that the NRC guidance state that “the second 8 hours [of a 16-hour shift] should not occur during a person’s normal sleep time” (NUREG/CR-1278, Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications).
- Studies have shown that the relative risk of having an accident increases dramatically after 9 consecutive hours on the job (Hanecke et al.,1998; DOT, 65FR25544; Colquhoun et al.,1996).
- Other studies have shown that task performance declines after 12 hours on a task (Folkard, 1997; Dawson and Reid, 1997; Rosa, 1991).
- Twelve hours per day was the limit recommended by nine experts who met in 1984 to develop recommendations for NUREG/CR-4248, "Recommendations for NRC Policy on Shift Scheduling and Overtime at Nuclear Power Plants," 1985.
- This limit is less restrictive than the limits imposed on nuclear power plant workers in other countries (see also Section 9).
- This limit is less restrictive than the limits imposed in several other industries that the staff reviewed (see also Section 9).

An individual should not be permitted to work more than 24 hours in any 48-hour period.

- This limit is intended to prevent acute fatigue.
- NUREG/CR-4248 recommends that this limit remain the same.
- Stakeholder comments indicate that this limit is problematic for personnel on 12-hour shifts in that it requires an authorized deviation when even small amounts of overtime are worked.

An individual should not be permitted to work more than 72 hours in any 7-day period.

- This limit could potentially allow a worker to work six 12-hour shifts per week continuously.
- Studies have shown that longer work schedules relate to fatigue (Colquhoun, 1996; Rosa, 1995).
- Human reliability analysis experts have recommended that the NRC set "a maximum of 60 hours in any 7-day period and a maximum of 100 hours in any 14-day period" noting studies indicating that fatigue from long work hours can result in personnel developing their own subjective standards of what is important (NUREG/CR-1278).
- NUREG/CR-4248 recommends a limit of 60 hours of work in a 7-day period.
- This limit is less restrictive than the limits imposed on nuclear power plant workers in other countries (see Section 9).
- This limit is less restrictive than the limits imposed in several other industries that the staff reviewed (see Section 9).
- This limit is intended to prevent cumulative fatigue; however, the limit of 72 hours in any 7-day period is inconsistent with research findings and use in other applications.

The limits all exclude shift turnover time.

- The policy statement excludes shift turnover times from the working hour limits, for practical considerations, but does not explicitly exclude any other parts of a workday (e.g., lunch, breaks).
- A limited number of licensees exclude periods from working hour calculations (e.g. lunch, breaks, training).
- The policy limits were developed on the basis that the normal day includes all parts of the workday except shift turnover.
- There is no technical justification for excluding rest breaks on the basis that such time does not contribute to fatigue. In a proposed revision of its hours of service regulation for motor carriers, the DOT concluded that "all time spent in any work must be counted as on-duty time, since all work can either induce fatigue or deprive the driver of sleep" (DOT, 65 FR 25558, 2000). The DOT conclusion is founded, in part, on the recommendations of an expert panel (Transportation Research Institute, 1998) and is consistent with a large body of research (Tucker et al., 1998; Akerstedt and Landstrom, 1998; Rosa, 1991).

A break of at least 8 hours should be allowed between work periods (including shift turnover time).

- On average, most humans physiologically require about 8 hours of sleep per night (Rosekind et al., 1997; Rosa, 1995).
- A break of 8 hours does not adhere to guidelines from the National Sleep Foundation, which recommends 12 hours off-duty time (National Sleep Foundation, 2000).
- Human reliability analysis experts have recommended that the NRC guidance be "a break of at least 12 hours between all work periods (NUREG/CR-1278).
- One study suggests that at least 16 hours be provided between shifts to provide adequate time for sleep (Kecklund and Akerstedt, 1995).
- The Insurance Institute for Highway Safety recommended a minimum of 12 to 14 hours off duty per day, citing Wylie et al. (1996).
- The Federal Motor Carrier Safety Administration reviewed the issue of rest or off-duty periods and found that continuous time off duty is important. The current regulations

require that drivers have at least 8 continuous hours off duty. A panel of experts criticized this requirement as inadequate because 8 hours off-duty time does not translate into 8 hours of sleep. Thus, the DOT proposal would require a 10-hour work break (DOT, 65 FR 25561).
- A break of 8 hours is less restrictive than the regulations for commercial aviation.

Except during extended shutdown periods, the use of overtime should be considered on an individual basis and not for the entire staff on a shift.

- The blanket relaxation that the policy statement allows for work scheduling during outages may no longer be consistent with the staff's understanding of the variations in plant risk that can occur during shutdown conditions and the heightened challenges to human performance presented by plant outage working conditions, including the increased dependence on manual operator action (NUREG-1449).
- Latent errors that may have previously occurred during an outage play an important role in significant accident sequence precursor (ASP) events (U.S. Nuclear Regulatory Commission, 2000).
- Team performance can be affected by fatigue (Harrison and Horne, 2000; NTSB, 1994).
- Some licensees may have interpreted the statement "for the entire staff on a shift" to mean that a single deviation could cover more than one individual, which was not the intent of the guidance.

Guideline Deviation Criteria – Industry data demonstrate that numerous deviations are authorized, indicating that guidance limiting deviations to very unusual circumstances is inadequate.

Recognizing that very unusual circumstances may require deviation from the guidelines, such deviations shall be authorized by the plant manager, or his deputy, or higher level management. Such authorization shall consider that significant reductions in the effectiveness of operating personnel would be highly unlikely.

- Deviations from the policy statement guidelines increase the risk of fatigue-induced impairment of attention, reasoning, computational skills, oral communications, and decisionmaking (Hanecker, 1998; Dawson and Reid, 1997; Folkard, 1997; Dinges, 1992).
- The policy statement does not set clear limits on the number of hours or days that individuals can be allowed to work at or above guideline limits.
- Data collected by the NEI (see Section 6) show that numerous deviations are authorized.

Procedures are encouraged that would allow licensed operators at the controls to be periodically relieved and assigned to other duties away from the control board during their tours of duty.

- Studies have shown that task variation can be of benefit for limited periods in counteracting degradations in alertness caused by fatigue (Folkard, 1997).

Authorized deviations to the working hour guidelines shall be documented and available for NRC review. Controls shall be included in the procedures such that individual overtime shall be reviewed monthly by the (Plant Superintendent) or his designee to assure that excessive hours have not been assigned (GLs 82-16 and 83-02 which disseminated the policy statement).

- NUREG/CR-4248 recommended guidelines to limit the amount of overtime accumulated over long periods, as well as guidelines to limit the plant manager's authority to deviate from the guidelines. NUREG/CR-4248 also recommended that authorization should be required for individuals working more than 192 hours in a 28-day period or 2260 hours in a year. The long-term limits on overtime were recommended to address the potential for cumulative fatigue effects on nuclear power plant personnel.
- The NRC has not provided any criteria to define "excessive hours."
- Other industries and countries have limits for periods longer than 7 days.

Routine deviation from the above guidelines is not authorized (GLs 82-16 and 83-02 which disseminated the policy statement).

- The UCS prepared a report on "Overtime and Staffing Problems in the Commercial Nuclear Power Industry" (letter from D. Lochbaum to Chairman Jackson, dated March 18, 1999), which presented concerns regarding the level of overtime being worked in the nuclear industry.
- Data collected by the NEI (see Section 6) show that numerous deviations are authorized.

<u>Summary</u>

- Studies of work scheduling, fatigue, and human performance indicate that scheduling of personnel at or near the limits of the NRC policy guidelines for controlling work hours during outages (e.g., 16 hours in a 24-hour period, 72 hours in any 7-day period, and the requirement for a minimum 8-hour break between work periods) can result in degraded human performance from work-related fatigue. Research concerning cumulative fatigue suggests that the NRC consider requirements to address the prolonged use of extended work hours of duties for personnel working in excess of these limits. These findings are generally consistent with past assessments of the NRC's policy guidelines.

- Information gathered from other industries and foreign nuclear power plants indicates that their working hour limits are generally more restrictive than those of the NRC policy statement. Although the adoption of specific limits in other industries and countries may have been influenced by the particular economic or workplace conditions in a given industry or country, the limits are generally consistent with the technical and research information described in this section.

- The policy statement guidelines are not responsive to the variations in plant risk that can occur during shutdown conditions and the heightened challenges to human performance presented by plant outage working conditions.

- Research concerning cumulative fatigue and work hour limits in other industries and countries suggests that the NRC should consider limits for periods longer than 7 days.

4.0 Implementation of the Policy Statement Through Technical Specifications

The staff reviewed the TSs for the 104 nuclear power units licensed to operate. The review revealed variations in how the policy statement was incorporated into TSs. In part, this appears to be a result of changes, over time, in the standard TSs. Working hour commitments could not be found for three units. The staff found that for each of these units, although there was no TS concerning work hours, the licensee had an administrative procedure in place that was largely consistent with the policy. Table 2 summarizes the number of units utilizing each version of the TSs. Version A was promulgated by GL 82-16, "NUREG-0737 Technical Specifications" (pressurized-water reactors [PWRs]) or GL 83-02, "NUREG-0737 Technical Specifications" (boiling-water reactors [BWRs]) as model TSs. The standard TSs incorporated this version and allowed a shorter TS wording (version B). In June 1999, the NRC amended the standard TSs (version C) to remove the specific work hour limits. This change was made in response to an NRC Regulatory Review Group report (August 1993), which cited the policy as an example of the NRC regulating by policy statement. The TSs was consequently revised to be less prescriptive. Licensees adopting the current standard TS relocate specific work hour controls to a licensee-controlled document. Subsequent changes to the work hour controls may be made in accordance with licensee procedure control processes.

Table 2. Working Hour Commitments		
Version	**Number of Units**	**Technical Specifications**
A	35	Administrative procedures shall be developed and implemented to limit the working hours of unit staff who perform safety-related functions (e.g., licensed SROs, licensed ROs, health physicists, auxiliary operators, and key maintenance personnel). Adequate shift coverage shall be maintained without routine heavy use of overtime. The objective shall be to have operating personnel work an [8 or 12] hour day, nominal 40 hour week while the unit is operating. However, in the event that unforeseen problems require substantial amounts of overtime to be used, or during extended periods of shutdown for refueling, major maintenance, or major plant modification, on a temporary basis the following guidelines shall be followed: 1. An individual should not be permitted to work more than 16 hours straight, excluding shift turnover time; 2. An individual should not be permitted to work more than 16 hours in any 24 hour period, nor more than 24 hours in any 48 hour period, nor more than 72 hours in any 7 day period, all excluding shift turnover time; 3. A break of at least 8 hours should be allowed between work periods, including shift turnover time; 4. Except during extended shutdown periods, the use of overtime should be considered on an individual basis and not for the entire staff on a shift. Any deviation from the above guidelines shall be authorized in advance by the [Plant Superintendent] or his designee, in accordance with approved administrative procedures, or by higher levels of management, in accordance with established procedures and with documentation of the basis for granting the deviation. Controls shall be included in the procedures such that individual overtime shall be reviewed monthly by the [Plant Superintendent] or his designee to ensure that excessive hours have not been assigned. Routine deviation from the above guidelines is not authorized.
Variations on A	9	Variations include 1) no description of the plant staff covered (1 unit), 2) no description of the controls to ensure adequate shift coverage without routine heavy use of overtime or nominal working hours/day/week (2 units) , 3) does not include wording of final paragraph requiring monthly reviews of individual overtime or prohibiting routine deviations from guidelines (7 units), and 4) does not include wording of final paragraph prohibiting deviations (1 unit).
B	9	The amount of overtime worked by unit staff members performing safety-related functions shall be limited in accordance with the NRC Policy Statement on working hours (Generic Letter 82-12).

Table 2. Working Hour Commitments		
Version	**Number of Units**	**Technical Specifications**
C	14	Administrative procedures shall be developed and implemented to limit the working hours of unit staff who perform safety-related functions (e.g., licensed SROs, licensed ROs, health physicists, auxiliary operators, and key maintenance personnel). The controls shall include guidelines on working hours that ensure adequate shift coverage shall be maintained without routine heavy use of overtime. Any deviation from the above guidelines shall be authorized in advance by the [Plant Superintendent] or his designee, in accordance with approved administrative procedures, or by higher levels of management, in accordance with established procedures and with documentation of the basis for granting the deviation. Controls shall be included in the procedures such that individual overtime shall be reviewed monthly by the [Plant Superintendent] or his designee to ensure that excessive hours have not been assigned. Routine deviation from the above guidelines is not authorized.
Variations on C	8	Variations include 1) no description of the plant staff covered (1 unit), 2) no discussion of the controls to ensure adequate shift coverage without routine use of overtime (3 units), 3) no description of the periodicity of individual overtime reviews, (6 units), and 4) no requirement for monthly reviews of individual overtime (1 unit).
D	11	Administrative procedures shall be developed and implemented to limit the working hours of unit staff who perform safety-related functions; e.g., senior reactor operators, reactor operators, health physicists, auxiliary operators, and key maintenance personnel. The amount of overtime worked by unit staff members performing safety-related functions shall be limited in accordance with the NRC Policy Statement on working hours (Generic Letter 82-12).
Variations on D	6	Variations include 1) no description of the plant staff covered (6 units) and 2) no discussion of the procedures limiting working hours (2 units).
E	4	Procedures shall be established to insure that NRC policy statement guidelines regarding working hours established for employees are followed. In addition, procedures will provide for documentation of authorized deviations from these guidelines and that the documentation is available for NRC review.
F	1	Written administrative procedures for shift overtime shall be established, implemented, and maintained.
G	1	The amount of overtime worked by unit staff members performing safety-related functions shall be limited and controlled in accordance with approved administrative procedures.
H	1	Administrative procedures shall be developed and implemented to limit the working hours of unit staff who perform safety-related functions (e.g., licensed SROs, licensed ROs, radiation protection technicians, auxiliary operators, and key maintenance personnel).
I	1	The amount of overtime worked by plant staff members performing safety-related functions shall be limited and controlled in accordance with an NRC approved program specified in plant procedures changes to the guidelines in these procedures shall be submitted to the NRC for review.

Table 2. Working Hour Commitments		
Version	**Number of Units**	**Technical Specifications**
J	1	Written procedures shall be established, implemented and maintained covering. . . Plant Staff Overtime, to limit the amount worked by staff performing safety-related functions in accordance with NRC Policy Statement on working hours (Generic Letter No. 82-12).
None	3	No commitment found in the TS.

Summary

There are numerous variations on how the policy statement was incorporated into TSs, including no commitment in TSs at three nuclear power units.

5.0 NRC's Regulatory Requirements Concerning Personnel Working Hours and Fatigue as a Basis for Enforcement Action

The principal components of the current regulatory framework for matters pertaining to working hours and fatigue are (1) the "Policy on Factors Causing Fatigue of Operating Personnel at Nuclear Reactors," as disseminated by GL 82-12; (2) plant TSs related to this policy statement; and (3) certain requirements of 10 CFR Part 26.

Policy Statement

It is well established that NRC guidance documents cannot prescribe requirements but merely set forth policy pronouncements or advice on a possible method of meeting a regulatory requirement. As a consequence, unless plants have incorporated the guidelines from the policy statement in a license condition or TSs, the guidelines are unenforceable.

Technical Specifications

As noted in Section 3, the TSs for all but three units include limits on the use of overtime. These TSs were implemented in response to GL 82-12, which requested that licensees establish TSs requiring administrative controls that follow the guidance of the policy statement.

A determination of whether a TS can be enforced without controversy rests on whether the language of the TS clearly states a requirement that the "reasonable person" can understand. As stated in Section 3, key terms of the TS have not been defined, and this deficiency results in inconsistent interpretation and implementation by licensees, as well as difficulty for the NRC staff when pursuing enforcement. Specifically, many TSs use the terms routine heavy use of overtime, unforeseen problems, and temporary basis. The NRC has not defined any of these terms and has not consistently pursued enforcement on the basis of the amount or frequency of overtime authorized. Rather, the NRC has tended to take enforcement action only when it could be shown that overtime was not authorized in writing before the work was performed. Recent data released by the NEI show that many licensees authorize more than a thousand deviations annually from the guidelines. In contrast, the policy statement anticipated that deviations would be required for "very unusual circumstances."

The staff does not believe that current TSs limiting working hours are sufficient to ensure that licensees meet the intent of the policy statement, or to ensure that the NRC can effectively and efficiently enforce the TS requirements.

The staff notes that the following additional factors complicate consistent enforcement of the TSs:

- The TSs are inconsistent in level of detail from site to site. Only three-quarters of the plant TSs include the quantitative working hour limit guidelines of the policy statement.

- The TSs are inconsistent in specific requirements. Some plant TSs require periodic review of overtime approvals to ensure that excessive hours have not been assigned, while other TSs contain no equivalent requirement.

- The scope of the personnel covered by the TSs has been interpreted inconsistently. The policy statement applies to personnel performing safety-related functions. The staff has found that Senior Reactor Operators (SROs), Reactor Operators (ROs), and non-licensed operators (NLOs) are the only categories of personnel covered at all of the sites that responded to the NEI survey. Although GL 83-14, "Definition of Key Maintenance Personnel (Clarification of GL 82-12)," dated March 7, 1983, defined key maintenance personnel as including personnel who work on safety-related equipment, some sites do not apply the TSs to maintenance personnel.

- Licensees for a limited number of sites have revised their methods for calculating work hours relative to the TS limits so as to reduce the number of deviations authorized without reducing the actual number of hours worked (e.g., by excluding breaks). As a result, the basic measure used to determine whether an individual's work hours are within or above the TS limits is not implemented consistently from site to site.

10 CFR Part 26, "Fitness for Duty Programs"

The general performance objectives of 10 CFR 26.10 require that licensees provide "reasonable assurance that nuclear power plant personnel . . . are not . . . mentally or physically impaired from any cause, which in any way adversely affects their ability to . . . perform their duties." Fitness-for-duty (FFD) programs must also provide reasonable measures for the early detection of personnel who are not fit to perform activities.

In addition, 10 CFR 26.20 states that licensees shall establish and implement written policies and procedures designed to meet the general performance objectives and specific requirements of 10 CFR Part 26. As a minimum, the policies and procedures must address the licensee's policy on FFD, as well as the use of illegal drugs and abuse of legal drugs.

Although 10 CFR Part 26 contains specific requirements pertaining to alcohol and drug usage, it does not include prescriptive requirements regarding fatigue. Rather, 10 CFR 26.20 uses general nonmandatory language to state that licensee policy "should" address other factors that can affect FFD, "such as mental stress, fatigue, and illness." As a result, it is more difficult to sustain a violation of the regulation in light of a licensee's failure to limit overtime hours. In addition, without a numerical limit on overtime hours, or a provision limiting overtime, it is likely that a range of overtime practices could be viewed as "reasonable" and in compliance with the

regulation. In enforcing this regulation, the staff must use a case-by-case approach that considers the reasonableness or soundness of licensees' measures in the circumstances presented. Enforcement may not be clear cut or "efficient," given that the staff may have differing views of what is reasonable or sound in such cases.

Summary

Only the mandatory and unambiguous provisions of the TSs and 10 CFR Part 26 relative to working hours and fatigue are readily enforceable. The broad and non-prescriptive provisions of 10 CFR Part 26 and TS pertaining to fatigue, in the absence of clearly defined terms or measures of fatigue, make it difficult to use this rule to achieve enforcement of matters concerning fatigue and working hours in an effective and efficient manner. The staff must demonstrate, on a case-by-case basis, that a given overtime practice was excessive or caused unacceptable fatigue. Therefore, the staff believes that rulemaking is needed to establish the regulatory basis necessary to ensure that licensees' work scheduling practices are consistent with the intent of the policy statement.

6.0 Industry Implementation of the Policy Statement

Although the NRC had conducted periodic inspections of the control of working hours for personnel performing safety-related functions, the staff lacked sufficient data to accurately characterize (1) industry control of working hours relative to the policy statement in the GL guidelines and (2) the current trends in the use of overtime relative to the policy statement. The NEI acknowledged the need to accurately characterize industry implementation of the policy statement and agreed to collect data for this purpose. The NEI collected the data in July 2000 and submitted the data to the NRC on August 29, 2000 (Nuclear Energy Institute, 2000). During that data collection process, the NEI asked licensees questions concerning their working hour controls, the scope of personnel to whom the controls apply, their use of deviations from the guidelines for the past 3 years, and their use of overtime for the same period.

Response Rate: Of the licensees for the 66 nuclear power plant sites in the United States, 47 (71%) responded to the NEI's survey, but not all sites provided complete data. The response rate for deviation data ranged from 28 sites (42%) providing outage deviations data for 1997 to 40 sites (61%) providing deviation data for operating periods in 1999. Similarly, the response rate to the request for overtime data ranged from 26 sites (39%) providing data for 1997 to 36 sites (55%) providing data for 1999. As a result, the staff cannot state with confidence that the data are representative of the distribution of U.S. nuclear power plant sites.

Analytical Constraints: As provided by the NEI, the data do not enable the staff to (1) distinguish a single-unit site from multiple-unit sites, (2) determine how many individuals at a site contributed to the total number of deviations, and (3) compare site responses across questions (e.g., determine the distribution of deviations over a given job category). The NEI did not provide supporting documents (i.e., administrative procedures for working hour limitations and FFD programs) to the staff. Despite these limitations, the staff was able to gain useful insights concerning the implementation of its policy statement at many sites.

Response Analysis:

Controls: All sites that responded indicated that they had administrative procedures that implement working hour policies. However, licensees for 16 of the 47 sites that responded indicated that their TSs did not include all of the restrictions of GL 82-12.

Scope: The survey requested data concerning how many individuals in each job category were subject to working hour limits. Licensees for 47 sites responded to this question. SROs, ROs, and NLOs are the only job categories covered at all of the sites that responded. No heath physics personnel were covered at four of the sites, contrary to the guidance of GL 82-12. In addition, GL 83-14 states that working hour limitations apply to key maintenance personnel; however, four sites did not cover instrumentation and control workers, two sites did not cover chemistry maintenance, four sites did not cover electrical maintenance, and four sites did not cover mechanical maintenance. The staff also found substantial variation among sites with regard to the number of personnel covered by plant work hour limits. The number of maintenance workers covered by working hour limitations at a site ranged from 0 to 554, the number of engineers and other personnel covered by working hour limitations ranged from 0 to 1471, and 16 sites had no engineers (e.g., system engineers) covered by working hour limitations.

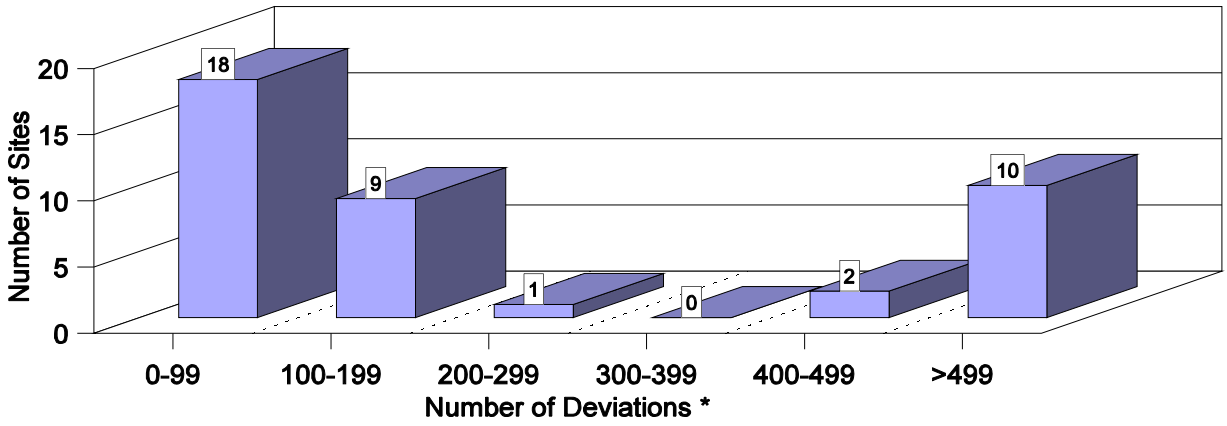
Distribution of Deviations: In response to the survey, sites reported the number of deviations that were authorized from the policy statement limits during outage and non-outage periods for 1997, 1998, and 1999. Table 3 shows that the most commonly used deviations during outage periods in 1999 were from the limit of 72 hours of work in any 7-day period (81.6 percent) and from the limit of 24 hours of work in any 48-hour period (15.1 percent). Authorized deviations for providing less than the minimum 8-hour break and for exceeding 16 hours of work in any 24-hour period collectively accounted for only a small percent of the authorized deviations during outages (3.3 percent). By contrast, the distribution of authorized deviations during non-outage periods was more even. Authorized deviations for working more than 16 hours in any 24-hour period accounted for a much larger percentage in non-outage periods (16.8 percent) than in outage periods (2.7 percent). Authorized deviations for exceeding 72 hours of work in any 7-day period (43.6 percent) and working more than 24 hours in any 48-hour period (36.7 percent) were, as in outage periods, the most common deviations during non-outage periods.

Table 3. Distribution of Deviations - 1999

Types of Authorized Deviations	During Outage Periods	During Non-Outage Periods
72 hours in any 7-day period	81.6%	43.6%
24 hours in any 48-hour period	15.1%	36.7%
16 hours in any 24-hour period	2.7%	16.8%
Less than the minimum 8-hour break	0.6%	3.0%

Frequency of Deviations: Figure 1 shows that during non-outage periods in 1999, licensees for about two-thirds of the 40 sites that responded authorized less than 200 deviations whereas about one-quarter of the sites authorized more than 500 deviations. The range of deviations during non-outage periods was 12 to 992.

Figure 1. Distribution of Sites by Number of Deviations Authorized During Non-Outage Periods - 1999



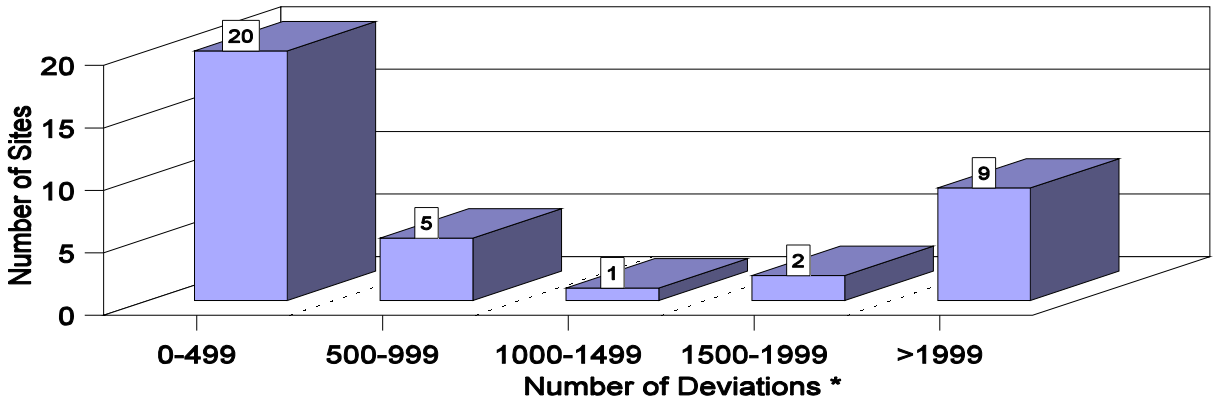
40 of 66 sites reporting data

* Range is 12-992 deviations

Figure 2 shows that during outage periods[1] in 1999, many of the survey respondents maintained relatively low numbers of deviations whereas a substantial minority authorized large numbers of deviations. Specifically, more than half of the 37 sites that responded authorized less than 500 deviations. In contrast, about one-quarter of the 37 sites authorized more than 2,000 deviations, including three sites that authorized more than 6,000 deviations. The range of deviations during outage periods was 7 to 7,553.

[1]For this survey, a site was considered to be in an outage if one or more units at a site was not in mode 1.

Figure 2. Distribution of Sites by Number of Deviations Authorized During Outage Periods - 1999

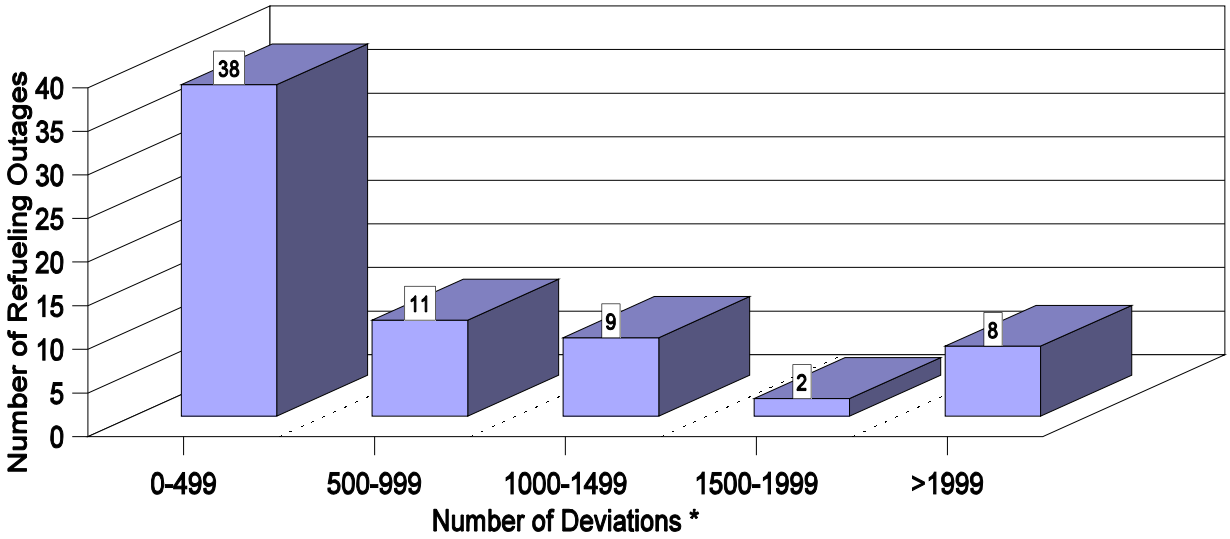


37 of 66 sites reporting data

* Range is 7-7,553 deviations

Survey respondents provided deviation data specific to 68 refueling outages. A wide variation was observed in the number of deviations authorized during a refueling outage. Twenty-five percent of the outages involved less than 100 deviations, whereas 28 percent of the refueling outages involved more than 1,000 deviations (Figure 3). No statistically significant correlation was found between the length of the refueling outage and the number of deviations authorized.

Figure 3. Distribution of Refueling Outages by Number of Deviations Authorized



Data Represents 68 Refueling Outages

* Range is 0-6,733 deviations

Overtime: Figure 4 shows annual overtime use for 1997, 1998, and 1999, and indicates that the percentage of personnel working in excess of 600 hours was higher in 1999 than 1997. At approximately one-fourth of the sites, more than 20 percent of the personnel covered by working hour limits work more than 600 hours of overtime annually. This number is more than two to three times the level allowed for personnel at some foreign nuclear power plants and more than twice the level recommended by an expert panel in 1985 (NUREG/CR-4248).

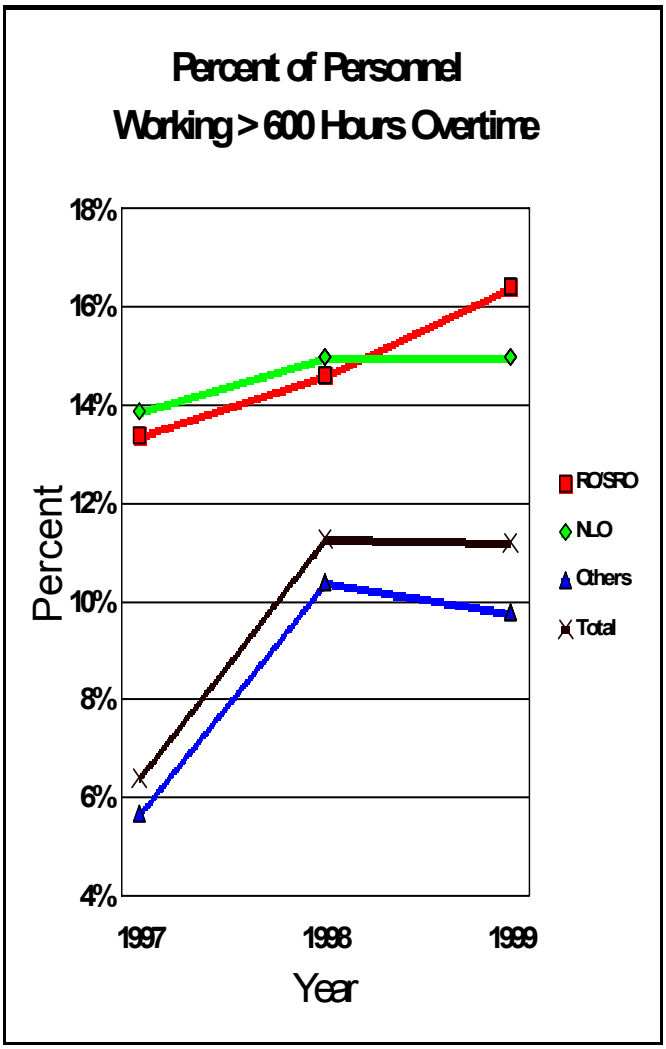


Figure 4. Percentage of Personnel Working More Than Six Hundred Hours of Overtime

NEI Position on Industry Implementation of the Policy Statement

On September 14, 2000, NRC held a public meeting to discuss the data collected by the NEI concerning the implementation of the policy statement. Both the NRC and the NEI presented their respective analyses of the data.

The NEI's assessment of the data is that it supports the Institute's position that rulemaking is not warranted. However, the NEI noted that variation in implementation of the policy statement at the sites may be a result of the guidance having been communicated through several documents, and consolidation of the guidance could be beneficial. The NEI also indicated that its interpretation of the data was that at most sites, the average number of deviations authorized for licensed and non-licensed operators was relatively small. The NEI's principal finding was that the number of deviations authorized per person is relatively low. This argument is supported by calculating an average number of deviations across time and personnel.

The staff does not believe that an analysis using calculated averages provides meaningful insights concerning fatigue for the following reasons:

- The NEI does not know the shape of the underlying distribution of deviations across time and personnel and, therefore, does not know if an average value is representative of the distribution.

- From a technical perspective, fatigue is experienced by individuals during specific periods of time. As a result, fatigue cannot be averaged across time and personnel, and such a statistic is potentially misleading and not technically sound.

- The staff also notes that from a regulatory perspective, the NRC must be mindful of individual licensee performance. This fact was quite evident in the distribution of deviations across sites. In addition, the staff is unable to verify or evaluate the calculation because the level of detail in the data provided to the staff does not allow the staff to perform such calculations.

Summary

Scope of Personnel

- There is inconsistency among sites in both the number and the type of personnel covered by plant work hour limits, and a few sites do not cover any maintenance personnel. This situation appears to be contrary to GL 83-14.

Use of Deviations

The frequency of guideline deviations at a substantial proportion of sites appears to be inconsistent with the intent of the policy because:

- During operating (non-outage) periods in 1999, licensees for one-third of the 40 sites that provided data authorized in excess of 200 deviations annually, while licensees for 3 sites authorized in excess of 800 deviations.

- During outage periods in 1999, licensees for about one-third of the 37 sites that provided data authorized in excess of 1,000 deviations, while licensees for 3 sites authorized in excess of 6,000 deviations annually.

- Licensees authorized more than 1,000 deviations in 28 percent of the refueling outages at plants that responded. In contrast, 25 percent of the refueling outages involved fewer than 100 deviations.

Use of Overtime

- Some sites have large percentages of personnel working in excess of 600 hours of overtime per year (i.e., more than two to three times the level allowed for operators at some foreign nuclear power plants, and more than twice the level recommended by a 1985 expert panel).

- The percentage of personnel working in excess of 600 hours of overtime was higher in 1999 than in 1997.

The staff believes that personnel working in excess of the policy statement guidance can be expected to be at increased risk of fatigue-induced impairment. However, the data illustrate that licensees for many sites do manage their work such that they have few deviations or little overtime.

7.0 Incidence of Fatigue-Related Events

Only a limited number of events at nuclear power plants have been directly attributed to fatigue. This may be in part be the result of the levels of defense-in-depth at nuclear power plants which are designed to reduce the potential for personnel errors to have consequential effects on plant safety. However, the **staff is not able to state with certainty the actual number of events that result from fatigue, and any estimates should be interpreted with caution.** In fact, plant incident reports typically do not contain much of the critical information needed to determine the contribution of human error. As noted in an EPRI report concerning control room operator alertness, “it is often necessary to rely on anecdotal evidence when presenting the case for the critical importance of operator alertness in the safe and efficient operation of a nuclear power plant” (EPRI, 1990).

One reason that the staff believes that the number of events attributed to fatigue may be underrepresented is that the research literature and operational data suggest that the conditions of shift work in nuclear power operations are such that one would reasonably expect personnel to be at risk of fatigue-induced impairment. This research includes the following examples:

- Studies show that personnel who work more than 12 hours a day are at increased risk of personnel error (Folkard, 1997; Dawson and Reid, 1997; Rosa, 1991). The NEI data concerning the use of deviations from the policy statement indicate that thousands of

person-hours are worked by personnel when they are at increased risk of impairment (see Section 6).

- Several studies show that nuclear power plant personnel exhibit circadian variations in alertness, and there are variations in the incidence of nuclear power plant personnel errors and events that coincide with these circadian variations in alertness (Bobko, 1998; Cox and Cox, 1996; Maloney, 1992).

- Studies show that personnel who are fatigued have impaired ability to maintain their attention (Harrison and Horne, 2000; Williamson, 2000; Bobko et al., 1998; Dawson and Reid, 1997; Dinges, 1995; Dinges, 1992; Rosa, 1991). The staff reviewed the Human Factors Information System (HFIS) data for 1997 through 1999 and found more than 5,000 instances of less-than-adequate independent verification, self-checking, and awareness or attention. These data were compared with HFIS data on findings related to the use of overtime. This analysis revealed that nuclear plants with repeated findings concerning use of overtime have a 50-percent higher incidence of HFIS causal factors related to fatigue.

Another reason that the staff believes that the number of events attributed to fatigue is underrepresented is that event investigation methodologies may not adequately address fatigue as a root cause, as indicated by the following factors:

- Depth of assessment – Most incidents at nuclear power plants are not subjected to an in-depth analysis that would identify fatigue as the underlying cause. Licensee event reporting requirements (10 CFR Parts 50.72 and 50.73) have not included causes of human performance problems at a level that would necessarily identify fatigue.

- Root cause assessment tools – There are no accepted criteria or structured approaches for evaluating the role of fatigue in accidents (Rosekind et al., 1997). As a result, when events are subjected to root cause assessment, fatigue may still not be identified. McCallum and Raby (1995) assessed investigation procedures employed by the NRC, the Federal Aviation Administration (FAA), and several international transport authorities. They found that the existing procedures do not adequately address the factors underlying fatigue as **a** causal element in cases in which the initial screening suggests fatigue as a factor.

- Lack of objective proof – When conducting a root cause analysis of events that involve personnel error, it is difficult to conclude that fatigue is a cause because there is little objective proof, absent the person sleeping, that the individual was impaired by fatigue. Even when nuclear plant personnel have been found with their eyes closed, they have asserted that they were not asleep, and investigators have concluded that the individual was "inattentive" (e.g., Peach Bottom, 1989).

- Ease of substantiating event causal factors – Fatigue degrades an individual's abilities but does not necessarily cause the event. For example, the alert individual recognizes an error in a procedure, whereas the fatigued individual does not and implements an incorrect procedure. As a result, an investigator would focus on objective contributing factors (e.g., the procedure error) or describe the behavior (e.g., cognitive error) without citing a contributor, such as fatigue, that is difficult to substantiate.

- Accuracy of post-event observations – When individuals are debriefed following an incident, they may appear alert because of the stimulation of responding to, or potential consequences of, the event. Impairment from fatigue would not be readily apparent in such circumstances.

- Accuracy of self-assessment – Although self-assessment of fatigue can often indicate the level of fatigue, research suggests that other factors may influence such self-assessments (Wylie et al., 1996; Dinges, 1995). In addition, studies have shown that individuals may believe that they are relatively more alert than indicated by physiological indices (Wylie et al., 1996; Dinges, 1995; Rosekind and Schwartz, 1988).

- Veracity of self-assessment – For various reasons, individuals may be reluctant to acknowledge that they were fatigued at the time of an event involving personnel error, including the implication that they were not fit for duty (Horne and Reyner, 1995).

One outcome of these challenges to identifying fatigue as a causal factor is that the investigation identifies the observable effects or consequences of fatigue, rather than fatigue itself.

Other agencies and investigative bodies have come to similar conclusions concerning the attribution of fatigue to events. A letter from Jim Hall, Chairman of the NTSB, to DOT Secretary Rodney E. Slater, dated June 1, 1999, included the following statement.

> Fatigue has remained a significant factor in transportation accidents since the Safety Board's 1989 recommendations were issued. Although generally accepted as a factor in transportation accidents, the exact number of accidents due to fatigue is difficult to determine and likely to be underestimated. The difficulty in determining the incidence of fatigue-related accidents is due, at least in part, to the difficulty in identifying fatigue as a causal or contributing factor in accidents. There is no comparable chemical test for identifying the presence of fatigue as there is for identifying the presence of drugs or alcohol; hence, it is often difficult to conclude unequivocally that fatigue was a causal or contributing factor in an accident. . . . Although the data are not available to statistically determine the incidence of fatigue, the transportation industry has recognized that fatigue is a major factor in transportation accidents.

Similarly, the DOT has concluded that fatigue statistics that are founded solely on accident reports underestimate the true extent of the problem (DOT, 65 FR 25545). In addition, the staff has learned that the Air Force Safety Center is revising the documentation to be used by accident investigation teams since they now believe that fatigue is underreported as a factor (Palmer et al., 1996). Also, a U.S. Coast Guard study suggests that direct measurement of fatigue may underestimate its true extent (Maritime Safety Committee, 1997). After the Coast Guard revised its procedures for investigating events, they found that the contribution of fatigue was *20 times greater* than previous estimates.

Summary

- Few events at U.S. nuclear power plants have been attributed to fatigue.

- The number of events attributed to fatigue should be interpreted with caution and cannot be reported with certainty.

- Many factors challenge the ability of event investigators to identify fatigue as a causal factor.

8.0 Scoping Assessment of the Sensitivity of Plant Core Damage Frequencies to Fatigue-Induced Impairment of Plant Personnel

Human errors are an important consideration in risk studies of nuclear power plants. In a probabilistic risk assessment (PRA) framework, the risk significance of fatigue effects can, in principle, be assessed through two classes of PRA model parameters. Specifically, these include the human error probabilities (HEPs), which deal largely but not exclusively with control room actions, and hardware-related parameters (e.g., initiating event rates and component failure probabilities, both of which can be affected by testing and maintenance practices). To date, such an assessment has not been done, partly because of the technical difficulties discussed below. However, since available empirical evidence, referenced below, indicates that fatigue can have a strong impact on human performance, it follows that further analysis to determine the impact of increased fatigue on human error probabilities applied in nuclear power plant PRAs may lead to important risk insights and is therefore warranted. Indeed, data suggest that fatigue, as caused by extended work hours or circadian rhythms, has significant effects on the likelihood of human error. Studies of accident rates in a wide range of industries (Hanecke, et al.,1998; Colquhoun, et al.,1996; Akerstedt, 1995; DOT, 65 FR 25544) indicate that the risk of accidents increases exponentially after 12 hours of work, and in some cases as little as 9 hours of work, and is more than two to three times the highest rates for 8 hour shifts when personnel are at work for 16 hours. It should be cautioned, however, it is not straightforward to determine the quantitative increase in the HEPs used in nuclear power plant PRAs. Factors that require consideration include the portion of time during which fatigue effects are operative, the nature of the tasks on which the data are based, differences in maintenance and control room activities, and the possibility that all HEPs are not universally affected. The staff is not aware of any PRA study that has considered the effects of fatigue.

NRC conducted a scoping study to quantify the potential risk impacts of errors caused by fatigued plant personnel. This study included sensitivity analyses that were performed by increasing the HEPs and quantifying the change in CDF for four nuclear power plants. The results of these sensitivity analyses show that global changes in HEPs can significantly affect the predicted core damage frequency (CDF). It should be emphasized that these results reflect only the sensitivity of core damage frequency to assumed changes in HEPs, and not the sensitivity of core damage frequency to changes in levels of operator fatigue. Additional work in the area of human reliability analysis will be necessary to understand the latter relationship.

Human errors may be sorted into categories for consideration in a probabilistic safety assessment (PSA). First, maintenance-related human errors may result in the failure of accident mitigation equipment. Second, human errors may prevent recovery of required equipment that failed during a plant event. Third, operators may err in mitigation-related actions such as alignment, operation, and control of systems or components. (For example, operators may fail to align alternate injection sources, fail to depressurize in certain scenarios, or fail to start and control pumps). The final category includes human errors that cannot be modeled using PSA techniques.

From a quantitative PSA viewpoint, the total CDF impact of increasing HEPs (as a result of fatigue) falls into the first three categories. Ideally, an analysis of the total CDF change should consider both internal and external initiating events during power operation as well as plant shutdown. However, because of the limited availability of plant models and time, this scoping study considered only at-power internal initiating events that proceed to core damage. There are shutdown-related probabilistic models for two of the plants included in this study (Grand Gulf and Surry), and these models may be useful if the scope of the study needs to be expanded. In addition, the sensitivity analyses were limited to varying the HEPs belonging to the third category. For this scoping study, maintenance-related and equipment recovery related fatigue failures were not included in the sensitivity study. Inclusion of these failures would increase the potential risk significance associated with fatigue; however, further study would be needed to evaluate their relative importance.

The Standardized Plant Analysis Risk (SPAR) models, Revision 3i, were chosen because they can be used to estimate the CDF of an internal event using a detailed HEP methodology. The human error modeling methodology used in these models was derived for the ASP Program. This methodology accounts for several performance shaping factors (PSFs) in calculating the HEPs, including FFD, which implicitly considers fatigue. For this scoping study, the base case HEPs for the types of actions in the third category were increased by multiples of 2, 5, and 10. SPAR models were used for the plants listed in Table 4:

Table 4. SPAR Model Baseline CDF

PLANT	DESIGN	SPAR MODEL BASELINE CDF
Watts Bar	Westinghouse 4-loop PWR with an ice condenser containment	4.4E-5/yr
Surry	Westinghouse 3-loop PWR with a subatmospheric containment	2.8E-5/yr
Grand Gulf	General Electric BWR 6 with a Mark III containment	1.1E-5/yr
Brunswick	General Electric BWR 4 with a Mark I containment	3.0E-5/yr

The results show that a small variation (a multiple of two) across the board for human errors related to accident mitigation can result in a CDF increase of greater than or equal to 1E-5/yr. Larger multipliers would result in a larger increase. The SPAR human error methodology includes the FFD PSF and, for events analysis, allows the SPAR model user to assume a multiplier of 5 for degraded fitness. This value results in CDF increases in the range of 1E-5/yr and 1E-4/yr. For a multiplier of 10, the increase was estimated to be near 1E-3/yr for the PWR sample plants, and 1E-4/yr for the BWR sample plants. The steam generator tube rupture initiating event was the risk-significant initiator for the PWRs, whereas the transient initiator was dominant for the BWRs. Caution should be used in reaching generic conclusions on the basis of these results because of differences in plant design and operation.

These findings broadly agree with three earlier risk sensitivity studies, including (1) NUREG/CR-5319, "Risk Sensitivity to Human Error"; (2) NUREG/CR-5527, "Risk Sensitivity to Human Error in the LaSalle PRA"; and (3) BNL L-117(2), "A Comparison of the Sensitivity of Risk to Human Errors in the Oconee and LaSalle PRAs." These studies showed that changes in HEPs of a factor of 5 result in an increase in CDF of a factor of between 4 and 33. In addition, the studies showed that a factor of two change in HEPs interpolates to a change in CDF of between 1E-5 and 1E-4. These findings demonstrate that relatively small changes in HEPs can be significant.

The preceding discussion suggests that the effects of fatigue could, under certain conditions, be risk significant. If risk insights are needed as part of continued fatigue-related studies, a number of conditions would have to be addressed. In particular, the effect of fatigue on HEPs for different actions modeled in the PRAs would need to be determined. The potential credit for fatigue management strategies (including both current licensee practices and possible additions), situations in which fatigue effects may be more prevalent (e.g., outage conditions), and the effects of fatigue on other PRA parameters (other than the HEPs) would also need to be assessed.

Summary

A scoping study of four plants was conducted using SPAR models to test the sensitivity of changes to the CDF when human error probabilities were varied to adjust for the effects of fatigue. The results show that a small variation (a multiple of two) across the board for human errors related to accident mitigation can result in a CDF increase of greater than or equal to 1E-5/yr. These results broadly agree with three earlier risk sensitivity studies that showed that a factor of two change in HEPs interpolates to a change in CDF of between 1.2E-5 and 1.2E-4. These findings indicate that the effects of fatigue may be risk significant.

9.0 Comparison of Working Hour Limits in Other Industries and at Foreign Nuclear Power Plants

The staff reviewed approaches taken by other Federal agencies and in other countries to address the potential for fatigue to adversely affect those personnel performing activities that can affect public safety. Table 5 summarizes the hourly limits on work and rest requirements in the policy statement, PRM-26-2, and the major occupations regulated by other agencies. The last two columns in Table 5 present the proposed revised limits for motor carrier drivers (65 FR 25610, 2000) and the limits for motor carrier drivers in Canada. Many of the other agency regulations are complicated and cover many aspects of their operations. (For example, the FAA has eight different regulations.) Only the most relevant regulations are included in the table. As can be seen from the table, the NRC requirements, collectively, are less restrictive than those of other Federal agencies that limit hours of work in private industry.

The other Federal agencies that the staff identified as regulating hours of work include the Federal Motor Carrier Safety Administration (FMCSA), the Federal Railroad Administration, the FAA, and the U.S. Coast Guard (personnel in safety-sensitive positions), the regulations of which limit the duty hours of personnel performing tasks important to public health and safety. For example, the FAA has promulgated duty hour regulations for flight crew members, dispatchers, aviation maintenance technicians, and air traffic controllers.

It is sometimes asserted that the work tasks and characteristics in nuclear power plants are different from the other occupations that have overtime controls; therefore, information from other occupations may be inapplicable. By comparison to many other work environments (e.g.,

Table 5. Hourly Limits on Work and Rest in the NRC's Policy Statement, the NRC Petition, and Other Industries

	NRC GL 82-12	NRC Petition	Comm. Pilot (flight time)	Air Force Pilots	Air Traffic Control	Marine	Rail	Truck Drivers (drive time)	Truck Drivers (Proposed)	Truck Drivers (Canada)
Hrs worked in a 24-hr period	16	16	8 to12	12	10	8 to15	12	10	12	13
Length of rest	8	16	9 to18			10	8 or 10	8	10	8
Hrs worked in a 48-hr period	24	24								
Hrs worked in a 72-hr period						36				
Hrs worked in a 7-day period	72	60 or 72	30 or 34		24			60	60	60
Hrs rest in a 7-day period			24						32 to 56	
Hrs worked in a 14-day period		108 or 132 or 144								
Hrs worked in a 30-day period			100 or 120	125						
Hrs worked in a year		2496 or 2704	1000 or 1200							

truck cabs, airplane cockpits), nuclear power plant control rooms, in general, provide relatively favorable light and temperature environments for mitigating the effects of fatigue.[2] Nuclear power plant operators are also able to move freely about the control room, interact with other operators, and engage in a variety of activities during the course of a work period. These factors are conducive to operators maintaining a higher level of subjective alertness. These factors, however, do not counteract an individual's physiological need for sleep and are not likely to completely mitigate the degradations in cognitive performance that result from sleep deprivation.

The physiological effects of fatigue are predominantly influenced by how long an individual is awake, how much sleep an individual has recently obtained, and the point at which the individual is in his or her circadian cycle of alertness (Kecklund et al., 1997). Research has also shown that team performance is affected by fatigue (Harrison and Horne, 2000; NTSB, 1994) suggesting that whereas members of a crew may help each other remain alert, a crew environment does not ensure fatigue will not degrade performance. The occupations regulated by the other Federal agencies are themselves different, ranging from marine officer and air traffic controller to maintenance personnel. Despite the diversity of occupations and tasks, the other Federal agencies have set stricter limits on hours of work and rest and have given management less authority to deviate from those limits. Although the stricter limits in other industries may reflect concerns about the influence of the specific work environments on fatigue, those limits may also reflect the potential in certain industries for operator performance degradations to directly affect safety.

General Regulatory Approach – The staff found that the NRC's general approach to plant personnel fatigue (i.e., limiting the number of hours worked) is consistent with the approach taken by other Federal agencies. However, the NRC has not put these limits in a regulation as have other Federal agencies that have a public safety mission. Instead, the NRC uses plant-specific TSs as the means to implement the limits (see Section 4).

Specific Limits – The staff found that the policy statement for allowing 16 hours in a 24-hour period and 72 hours in a 7-day period is less restrictive than the limits imposed in several of the other industries reviewed; however, none of the other industries include the limit of no more than 24 hours of work in any 48-hour period. In addition, the NRC's policy guidance for a minimum break of at least 8 hours between work periods is the shortest of the surveyed industries. The NRC's policy statement also does not provide guidance to limit work hours accumulated over periods longer than 7 days, whereas commercial and air force pilots have limits for longer periods of time.

Deviations – The policy statement allows flexibility that is not provided in other agency regulations. Although the objective of the policy statement is to have 8- or 12-hour days and nominal 40-hour weeks, limits are set for unforeseen problems and extended periods of shutdown. A few other agencies allow limited flexibility. For example, regulations for seamen apply "except in an emergency when life or property [is] endangered" (46 CFR 8104 (b)).

[2] Low frequency noise levels from sources such as ventilation systems and rotating equipment may be at levels conducive to fatigue at some plants. Environmental conditions for operator activities outside of the control room are highly variable.

Limits for Nuclear Power Plant Personnel in Other Countries – In addition to the survey of working hours in other industries, the staff surveyed regulators of nuclear plants in other countries. The limits are set by national labor law, regulations, or union agreements. These limits are consistent with the technical and research information described in Section 3, but in some cases their adoption may have been influenced by economic conditions. The information presented in Table 6 was extracted from the data for ease of comparison. The actual data and source documents are more detailed. The information in the table includes working hour information from EdF, the utility in France; the Health and Safety Executive in the United Kingdom; SKI, the regulator in Sweden; STUK in Finland; HSK, the Swiss regulator; JAERI in Japan; HAEA, the Hungarian regulator; CSN, the Spanish Regulatory Agency; and the Canadian Nuclear Safety Commission. The last column includes the general guidance from the European Union (EU) on working hours (Directive 93/104/EC of 23 November 1993), which many EU countries have adopted. The EU conventions are based on research findings and are quite restrictive, but individual countries and industries do modify them for their particular situation. As can be seen from Table 6, the foreign limits on working hours are more restrictive than the limits stated in the current NRC policy statement. Except for Finland, the maximum hours in a 24-hour period are either 8 or 12, as compared to the 16 allowed by the NRC. The highest weekly maximum is 48 hours, as opposed to the 72 hours allowed in the United States, Spain, and Finland. There is no category for hours worked in a 48-hour period; however, there are monthly and yearly maximums that are not included in the NRC policy statement. The staff also obtained information on the average number of deviations expected in a year, the extent of those deviations, and the reasons for such deviations. Typically, the utilities would average one period a year during which deviations would be allowed on a plant-wide basis for outages or emergencies. The extent of the deviations would be 1 to 2 hours a day for France and Japan, but as many as 6 to 8 hours a day in the United Kingdom.

Summary

- The NRC policy statement is generally the least restrictive of the Federal agencies that regulate hours of work in other industries and allows more flexibility than other agency regulations.

- Tasks and task environment can influence whether an individual feels alert or drowsy but the physiological effects of fatigue are predominantly influenced by how long an individual is awake, how much sleep the individual has recently obtained, and the point at which the individual is in his or her circadian cycle of alertness.

- The foreign limits on working hours are more restrictive than those of the NRC policy statement and apply to a broader group of personnel. These limits are generally consistent with the technical and research information described in Section 3, but in some cases their adoption may have been influenced by economic conditions.

Table 6. Hourly Limits on Work and Rest in the Foreign Nuclear Industry

	France	UK	Sweden	Finland	Switzerland	Japan	Hungary	Spain*	Canada	EU-Gen
Hrs worked in a 24-hr period	10 w/o auth.; 12 w/auth.	8 hrs in 24 (Avg. over 17 wks)		16		8	8 hr; 6 hr hazardous duty	12	12	
Length of break				8 hrs between work periods 24 hrs/wk			11 hrs between work periods	8 hrs between work periods	72 hrs after three12-hr shifts; 48 hrs after two12-hr night shifts	11
Hrs worked in a 7-day period	35	48 hrs/wk (avg. over 17 weeks)	Regular 40/wk; Shift workers 36/wk	72	45	40		72	48	48
Hrs worked in a 30-day period		120	50 hrs OT/month special reason				180 on-call hrs			
Hrs worked in a year	1600	2050	150 hrs OT/yr.	250 OT	170 hrs OT		200 hrs OT		2480	
Night work										8/24
Freq. of deviation	Once/yr Emerg. or outages	Once/yr Emerg. or outages		<1/yr Operational events	Emerg.	Emerg.	Emerg.	As authorized by Plant Super.	Emerg.; need Ministerial permit	
Extent of deviation	1-2 hrs/day	6-8 hrs/day		> 8hrs	2 hrs/day	1-2 hrs/day	Once/wk, 6-8hrs/day			
Personnel covered	All	All	All	All, plus special limits for operators	All	All	All	Shift personnel and operators	All non-management	All
Basis	National labor law	Regulation based on EU convention	National labor law and union agreement	National labor law and union agreement	National labor law	National labor law	National labor law and union agreement	Union Agreement	National labor law and union agreement	

*for 5 of 9 plants

10.0 Description of Fatigue Management Programs

In addition to surveying current regulations, some of which were established many years ago, the working group surveyed current initiatives in industry to address fatigue. Fatigue Management Programs (FMPs), sometimes referred to as Alertness management programs, are becoming prevalent in many industries that require shift work. These programs are being championed by industry and labor organizations throughout the transportation and process industries. Most are derived from work performed for the military and the aerospace industry. Dr. Mark Rosekind, formerly of the National Aeronautics and Space Administration (NASA)/Ames, is often credited for his work in defining the broad elements necessary for an effective FMP (Table 7). The major elements of FMPs include prevention (e.g., work hour limits, rest requirements, training, health screening), detection and monitoring, mitigation, and evaluation. The NASA/Ames program is widely used as it is viewed as providing the most advanced material while still being predicated on scientific consensus.

Several Government agencies (the FMCSA, FAA), consultants (Rosekind and Associates; Circadian Technologies, Inc.), industries (railroads and truckers), and companies (rail and shipping) have implemented or expanded upon the NASA/Ames approach. For example, most major rail routes west of the Mississippi River use FMPs that allow and encourage napping to maintain alertness. Fatigue management is also used in Australia in the rail, trucking, and electric power industries. Some companies have also incorporated risk management in their FMPs. To minimize system risk, analytical tools are used to integrate the risk from personnel impairment with operational risk assessment to support decisions concerning scheduling and job assignments. A similar approach has been implemented by a rail transport company in Canada. Most tailor the generic FMP elements to their specific industries, companies, or work sites. One private firm claims to have provided assistance in developing and implementing FMPs to 60 percent of the Fortune 500 firms. Research is underway regarding specific approaches in specific environments (e.g., testing of different shift schedules at railroads and the use of napping while at work). Some future countermeasures have much research yet to be done before they are completely understood. However, other than limited self-assessments and program refinements, there have not been any publicly available formal studies to assess the overall effectiveness of FMPs.

Table 7. Elements of a Fatigue Management Program

Prevention
● Training, for example, sleep hygiene; effects of shift work, diet, exercise, alcohol, caffeine, medications, and sleep environment; and circadian physiology
● Work hour limits and rest requirements
● Medical review for sleep disorders, for example, health screening programs
Detection and Monitoring
● Supervisory observation
● Self-assessment
● Alertness monitoring

- Analytical tools for assessing fatigue
- Root cause analysis

Mitigation

- Error reduction techniques, for example, communications, self-checking, independent verification
- Task/access limitations, for example, work distribution, risk considerations
- Rest provisions, for example, rest breaks, napping

Research and Evaluation

- Bright light technology
- Melatonin
- Alertness monitoring systems
- Environmental considerations, for example, lighting, noise, temperature

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The DOT has identified operator fatigue as a significant issue affecting all transportation modes and consequently classifies operator fatigue management as a DOT "Flagship Initiative." In August 2000, the DOT held a conference on "Operator Fatigue Management." The conference brought together representatives from industry, labor, Government, and the research community to discuss their plans for a cross-modal research program in fatigue management. The DOT's proposed effort is budgeted at $12 million, with the intent to have transportation industry partners match the DOT resources over 3 years. The elements of this initiative are to develop a fatigue management reference resource, to investigate fatigue management analytical systems, and to develop fatigue management evaluation tools and methods. The work is to be coordinated by the DOT Human Factors Coordinating Committee across all modes of transportation.

On October 26-27, 2000, the Federal Transit Administration, the American Public Transportation Association, the Community Transportation Association of American, and the National Sleep Foundation held a symposium on tools for managing fatigue in transit. The symposium included an extensive cross section of fatigue experts and others concerned with fatigue and its effects on transit. Operational and labor issues were emphasized.

Summary

Several other industries have addressed the matter of personnel fatigue through industry - labor initiatives to develop fatigue management programs. These programs combine several methods to prevent, detect and mitigate fatigue and include elements of working hour limits and rest requirements.

11.0 Conclusions

Nuclear power plants are designed, and their operation controlled, in a manner to minimize the consequences of potential human errors on plant operational safety. As a consequence, there are measures and barriers that can serve to reduce the probability of fatigue induced errors at nuclear power plants resulting in events leading to core damage or off-site release of

radioactive materials. Nevertheless, the assessment of the policy indicates that from both technical and regulatory perspectives, there are attributes of the policy and its implementation that cause the policy to be less than wholly effective in ensuring that fatigue does not significantly degrade the ability of personnel to perform functions important to plant operational safety.

The assessment of the technical adequacy of the guidelines indicated that - -

- Studies of work scheduling, fatigue, and human performance indicate that scheduling of personnel at or near the limits of the NRC policy guidelines for controlling work hours during outages can result in degraded human performance from work-related fatigue.

- Personnel whose work hours exceed the policy guidelines (e.g., when guideline deviations are authorized) are at increased risk of impairment and of committing fatigue-induced errors.

- The policy statement does not provide clear guidance on the magnitude or frequency of deviations from the guidelines that are acceptable.

- The policy statement guidelines are not responsive to the variations in plant risk that can occur during shutdown conditions and the heightened challenges to human performance presented by plant outage working conditions.

- The policy statement addresses only working hours, not the fundamental issue of fatigue.

The staff also reviewed individual plant TSs and assessed the ability of the NRC to enforce its requirements concerning working hours and fatigue. The staff found that - -

- There are numerous variations on how the policy statement was incorporated into TSs, including no reference in TSs at three nuclear power units.

- Key terms of the TSs have not been defined, resulting in inconsistent interpretation and implementation.

- Only the mandatory and unambiguous provisions of the TSs and Part 26 relative to working hours and fatigue are readily enforceable in an efficient and effective manner. Substantial effort is required to enforce the broad and non-prescriptive provisions, even in extreme circumstances.

The assessment of industry implementation of the policy also indicates deficiencies. Some of these problems might be traced to lack of definition of some terms (e.g., very unusual circumstances) and inconsistencies in interpretation. Data reviewed in this assessment, which show that - -

- There is inconsistency among sites in the scope of personnel covered by plant work hour limits, and a few sites do not cover any maintenance personnel. This circumstance appears to be contrary to GL 83-14.

- The frequency of guideline deviations at a substantial proportion of sites appears to be inconsistent with the intent of the policy. At one-third of the sites that responded, more than a thousand guideline deviations are authorized annually.

- Licensees of many sites manage their work such that they have few deviations or little overtime.

- Some sites have large percentages of personnel working in excess of 600 hours of overtime per year. The percentage of personnel working in excess of 600 hours of overtime was higher in 1999 than in 1997.

The staff considered the incidence of events attributed to fatigue at nuclear power plants and found that there were few. This may be in part the result of the levels of defense-in-depth at nuclear power plants which are designed to reduce the potential for personnel errors to have consequential effects on plant safety. However, the staff believes that the number of events attributed to fatigue should be interpreted with caution and cannot be reported with certainty. The staff's conclusions were based on the following considerations:

- R**esearch literature and operational data suggest that the conditions of shift work in nuclear power operations are such that one would reasonably expect personnel to be at risk of fatigue-induced impairment.**

- Studies show that nuclear power plant personnel exhibit circadian variations in alertness and that there are variations in the incidence of nuclear power plant personnel errors and events that coincide with these circadian variations in alertness.

- Several factors challenge the ability of investigators to identify fatigue as the cause of an event, including the fact that fatigue cannot be objectively proven. As a result, event investigations are more likely to identify the observable effects of fatigue (e.g., inattention or cognitive error), rather than fatigue itself.

As part of the policy assessment, the staff conducted preliminary assessments of the influence of fatigue on plant risk. Although a more detailed study would be necessary to have confidence in the assessed influence of fatigue on plant risk, the preliminary findings indicate that the effects of fatigue may be risk significant. These findings include the following:

- Studies concerning extended work hours (e.g., more than 12 hours) suggest that fatigue-induced personnel impairment can increase human error probabilities by a factor of more than two to three times baseline human error probabilities.

- A scoping study using SPAR models shows that a small variation (a multiple of two) across the board for human errors related to accident mitigation can result in a CDF increase of greater than or equal to 1E-5/yr.

- These results broadly agree with three earlier risk sensitivity studies that showed that a factor of 2 change in HEPs interpolates to a change in CDF of between 1.2E-5 and 1.2E-4.

The staff reviewed the regulatory approaches and limits of other agencies that controlled working hours of personnel for the purpose of protecting public health and safety. Limits in other settings can be influenced by a variety of practical considerations, such as operational constraints in the industry and socioeconomic factors. Tasks and task environments can also influence whether an individual feels drowsy or alert and may have also influenced the limits specified in a particular industry. Nevertheless, research has shown that the physiological effects of fatigue are predominantly influenced not by tasks but by how long an individual is awake and at what point the individual is in his or her circadian cycle of alertness. Consequently, the predominant influence, human physiology, is common to all industries, and the staff believes that considering the limits in other industries collectively can provide useful insights. The staff drew the following conclusions:

- Collectively, the NRC guidelines are less restrictive than limits imposed by Federal agencies that regulate hours of work in other industries.

- The NRC policy statement allows more flexibility than the regulations of other agencies.

- The working hour limits on nuclear power plant workers in other countries are more restrictive than those of the NRC policy statement.

- Other industries and countries have limits for periods of more than seven days.

- The limits in other industries and countries generally appear more consistent with limits that research on work scheduling and fatigue would suggest are appropriate for ensuring human reliability.

On the basis of these findings, the staff believes that weaknesses in the NRC policy statement have diminished its effectiveness. However, the staff also believes that there is an adequate technical basis and relevant experience to develop new requirements that are technically sound and practical in a nuclear plant operational setting. Current approaches being pursued by some industries in the United States and abroad suggest that the NRC should consider methods that address the fundamental issue of fatigue from any cause, not just working hours. Such measures, as implemented in FMPs, include prevention (e.g., work hour limits, rest requirements, training, health screening), detection and monitoring, mitigation, and evaluation.

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